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Searching for the ‘sweet-spot’: Demonstrating the contribution of shape analysis tools in stimuli creation

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Abstract

Within design research several well-known principles have been identified that influence aesthetic pleasure for product designs. More specifically, these design principles indicate an optimal balance on a certain design attribute that receives the highest aesthetic pleasure (e.g., Most Advanced, Yet Acceptable). While these go far in explaining the effects of design on appraisal, the nature of the stimuli used in these studies makes it difficult to identify exactly where this optimal balance lies and thus does not inform a designer on how to adjust a given attribute to create an aesthetically pleasing product design. In this study, we conduct a meta analysis on one such study exploring the design principle Most Advanced, Yet Acceptable and demonstrate the application of shape comparison tools in relating the sweet-spot in terms of changes in product shape. Results from the application show the way in which quantifying difference in shape can help to identify aspects of shape where minor changes result in substantial increases/decreases in aesthetic pleasure, as well as its use in relating a value of difference to optimum values of aesthetic pleasure.

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Introduction

In design research there has been considerable attention to aesthetics and in particular which combination of product attributes and properties are deemed more aesthetically pleasing than others. A focus of this type of research is in identifying and verifying the existence of aesthetic design principles that indicate an optimal balance in a combination of certain design attributes (e.g., Most Advanced, Yet Acceptable, Unity-in-Variety, Golden ratio). These principles all assume the existence of a certain 'sweet spot': an optimal balance between the attributes of a design principle that results in the most positive appreciation[1]. For example, people appreciate novelty, but only if the product remains sufficiently recognizable [2, 3]. Identification of these instances without doubt has value in providing designers with guides and basis to create designs that are optimally aesthetically appraised which can therefore justify design decisions. However currently these principles fall short in specifying what (for a given design context) constitutes the optimal design in relation to its physical properties (e.g. shape, color, material). This paper presents the first step toward providing a means for research into aesthetics to be able to specify the optimum (sweet spot) for a certain design attribute that results in the highest aesthetic pleasure for a given set of designs. We do so by formally measuring exact differences in appearance of product allows us to identify the sweet spot. In this study we focus on the design principle Most Advanced, Yet Acceptable by reassessing stimuli used in[2], in which typicality of toasters and juicers were manipulated in controlled steps of angularity.

1. Background.

1.1. Stimuli creation in research into typicality and aesthetic pleasure

Stimuli are an essential component of research into aesthetics. Typically studies revolve around a procedure where stimuli are exposed to participants and their responses recorded [2-5]. A significant study that exemplifies this type of procedure is that in[3]. In this study the influence of the concepts of novelty and typicality in product design on aesthetic preference is explored. The study used a selection of existing products (home telephones, tea kettles and mid-range cars) to explore this, though pre-tests were rated as being more or less novel/typical. This allowed for correlational analyses to demonstrate the existence of an optimal balance between these factors. While the finding is important, with respect to practicing designers, the use of existing products as stimuli make it difficult to highlight which designed properties should be manipulated to achieve optimal balance between novelty and typicality in other cases.

The study in [2] acknowledges the shortcomings of using existing products as stimuli. These primarily include the effects of other factors such as the influence of brand or perceived functionality of products that would confound judgments on aesthetics. To isolate these factors, in their study stimuli were created to explore the influence of typicality and arousal on aesthetic preference. By employing a trained designer to create stimuli variations of realistic looking products were created. Typicality of these stimuli was manipulated by gradually deviating the products' shapes (angularity) from the prototype shape (the shape typically associated with a certain product category) while minimizing the influence of confounding factors. In this study, juicers were created that gradually became more angular and thus less typical and toasters that became less angular and thus less typical. Results for juicers showed the expected curvilinear relationship between shape deviation and aesthetic pleasure, while toasters showed a linear effect of shape-deviation with aesthetic pleasure. The reason put forward for why no optimum was identified for toasters was that due to trying to minimize confounds (changing shape so much that functionality would be perceived differently), changes in shape were limited and thus did not reach enough deviation to identify a dip in aesthetic pleasure. The outcome of this study nevertheless verifies the existence of a sweet spot where an optimal degree of typicality results in maximum aesthetic pleasure. The effect of arousal on aesthetic pleasure was also investigated by varying color saturation, not shape hence we will not include this aspect of the study in our discussion and analysis. Considering the reliability of findings to design practice, the use of created stimuli does show the closest design to where the sweet spot lies. However the relative difference between variants is only judged subjectively so feedback on the degree of difference between variant designs and hence the degree of difference that constitutes the exact sweet spot cannot be determined. In order to be able to more accurately inform

designers on how an optimal design can be created, we argue for formally and objectively measuring the exact physical differences between stimuli.

1.2. Shape comparison in research into product appearance

There is a substantial body of work into comparison of shapes in images or in 3d models for the purposes of shape searching and retrieval of similar models and comparing and measuring differences [6, 7]. Using such techniques as a means to assess how appearance influences different factors relevant to design research is relatively novel. Previously, comparison measures have been used to assess appearance differences from the perspective of brand identity and styling strategy. [8] provides a case study where shape comparison tools are used to examine the evolution in shape of beer bottle design over the history of a brand. In [8] the intention for the use of shape comparison tools was to provide objective benchmarks as to the degree of difference that was applied in key styling changes over the evolution of the beer brand. The study is relevant here as it illustrates the ability of this shape comparison tool to be used in quantifying the degree of difference in shape of designs. In this study, shape comparison tools measure and quantify the degree of difference between each evolution of the designs, achieved by means of measuring the distance between comparable points on the surface of digital models of the bottles (Hausdorff difference).

2. Aim

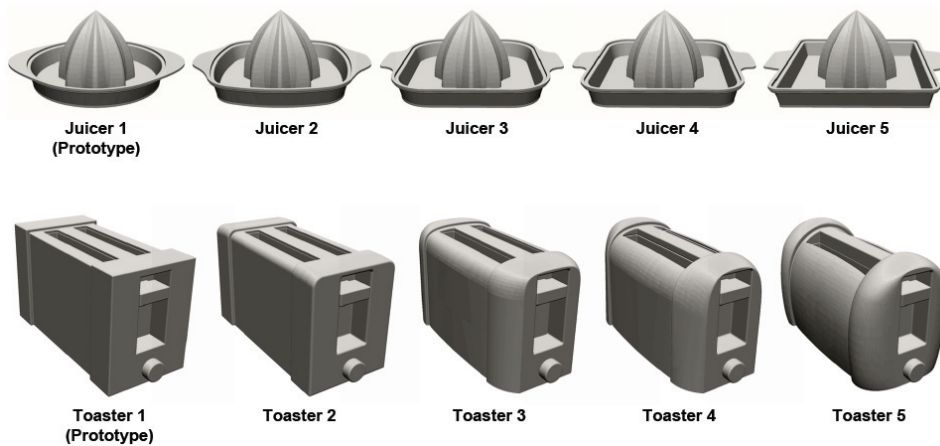
By reviewing the literature, we have seen that there is substantial knowledge of various design principles relating to aesthetics and stimuli, however due to the nature of stimuli used, it is difficult to identify the exact optimum on a design attribute. Hence, the overall aim of this research is to improve the reliability of the optimums identified through experimentation with changes in typicality, manipulated through angularity of the designed stimuli. To achieve this we apply the shape comparison technique used in [8] to perform a meta-analysis on the stimuli created in [2] in order to demonstrate the way in which measures for degree of difference facilitate the ability to identify the optimum deviation from the prototype. In this research we will plot the formal measurements of shape differences to aesthetic pleasure of these stimuli found in [2] to identify the exact sweet spot (optimum). In doing so we aim to provide a case study to demonstrate the additional value to research into design/aesthetics of conducting formal and objective measurement analyses on the stimuli created for experiments.

3. Method

As stated above we revisit the experiments conducted in [2] exploring the effects of typicality in product designs. This study was selected as it includes two examples of designed stimuli deviating on the basis of angularity (Toasters and Juicers) that are evenly varied in terms of their typicality (judged by the designer) from a prototype design and rated in terms of aesthetic pleasure. In addition, the sets of stimuli provide contrasting examples of modifying angularity where the Toaster prototype is most angular and the Juicer prototype is most rounded. Images of the stimuli are included in Figure 1.

3.1. Shape analysis

The shape comparison used in this study is a surface comparison tool, “CloudCompare” [9] as used in [8]. This technique compares 3d digital models of the stimuli. The outer surfaces of the models are represented as point clouds consisting of 100000 evenly spaced points. The distance from each point on the base model to the nearest point on the compared model is calculated. This tool is preferable for a secondary function of being able to visualize the location and magnitude of differences on the digital models (discussed further in section 6).

a) Stimuli Analysed**b) Aesthetic Pleasure Ratings**

Stimuli	Rating
Juicer 1	5.20
Juicer 2	5.26
Juicer 3	5.29
Juicer 4	5.26
Juicer 5	4.88
<hr/>	
Toaster 1	3.93
Toaster 2	4.28
Toaster 3	4.31
Toaster 4	4.36
Toaster 5	4.58

Fig. 1. (a) Designs of toasters deviating from an angular prototype in four steps (Bottom) and designs of juicers deviating from the rounded prototype in four steps (Top); (b) Respective ratings for aesthetic pleasure for each of the stimuli (from [2]).

3.2. Comparison of stimuli: Measures for difference in shape

The surface-point comparison creates a large volume of data consisting of all the measurements for point surface difference. An absolute average of these values is used to create an overall measure of difference. The absolute value is used as this study is focused on difference in shape irrespective of the direction (increase or decrease in size). This comparison and calculation of average is repeated for all stimuli comparisons.

Two types of comparison were made. To compare the relative magnitude of changes in shape for each deviation from the prototype, the stimuli were compared sequentially (see Figure 1: stimuli 1-2, stimuli 2-3, stimuli 3-4, and stimuli 4-5). For the purpose of plotting relative magnitude of difference against ratings for aesthetic pleasure, a datum approach is used where stimuli are compared in terms of their deviation from the prototype (see Figure 1: 1-2, model 1-3, model 1-4, and model 1-5).

4. Results

Following the analysis of stimuli, it is possible to plot the difference in shape against the rating for aesthetic pleasure for each stimulus. Values for difference in shape are plotted on the X-axis. The average rating for aesthetic pleasure (gathered from the results in [2]) for each model form the values on the Y-axis. Each point is numbered to reflect the stimulus where 1 represents the prototype and subsequent numbers represent steps in changes in shape to vary typicality.

4.1. Juicers

We now focus on the results of this application to the Juicers as this is the study which generates a curvilinear relationship between typicality and aesthetic pleasure (see Figure 1 (b)). Chart (a) in Figure 2 plots the measure for difference between each stimulus. This is shown sequentially to give an understanding of the magnitude of the difference in shape designed in each stimulus. The major observation from this plot is that the magnitude of difference in each step is not consistent, but decreases over each step.

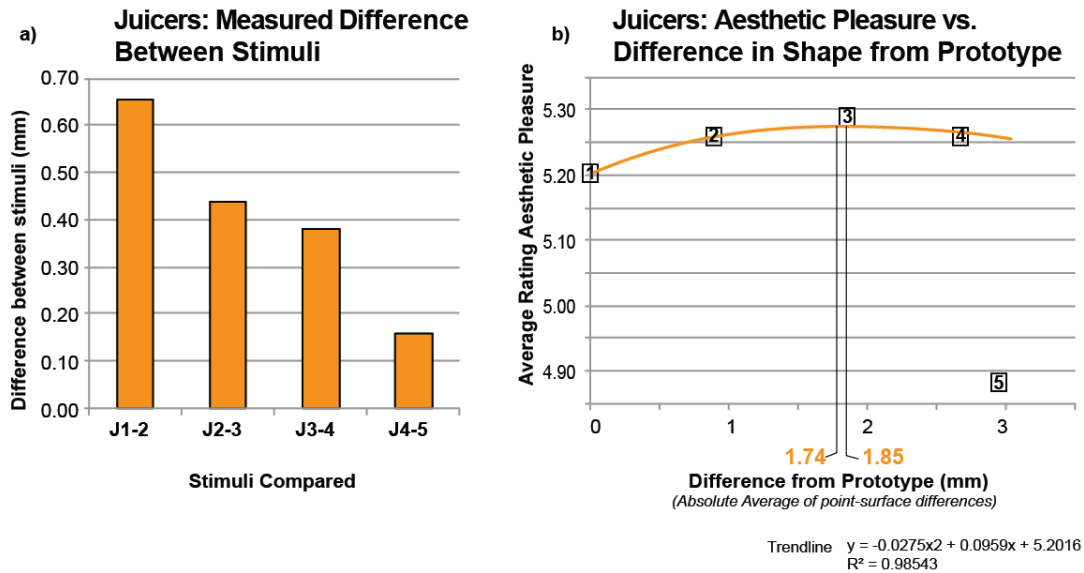


Fig. 2. Magnitude of difference between variant juicer stimuli (a) and scatter plot showing average rating for aesthetic pleasure versus difference from prototype showing the sweet spot difference (1.74mm) to maximize aesthetic pleasure (b).

Plot b) shows the stimuli placed on a scatter plot. A 2nd order polynomial trend-line is fitted to the scatter plot to reflect the curvilinear relationship described in [2]. The most extreme variant from the prototype (Juicer 5) was not included in the calculation of the trend line as it was deemed to be an outlier on the grounds that it is ‘unacceptably’ atypical compared with the other models. Note the R^2 value when omitting Juicer 5 of close to 1. Now inspecting the trend line (Figure 2b) it can be seen that model 3 lies very close to the sweet spot (optimum). Reading from the graph the sweet spot for difference from the prototype lies at 1.74mm, marginally smaller difference than the difference reflected in Juicer 3 (1.85mm).

Of note with Juicer 5, being able to plot relative difference in shape shows that there is a steep decline in aesthetic response in the relatively small difference between Juicer 4 and Juicer 5. Hence while it is the sweet-spot that is the primary focus, the plot suggests that there is a critical degree of difference between model 4 and 5 that results in a significant drop in aesthetic pleasure (the “sour spot”?).

4.2. Toasters

The relative difference in shape between each toaster variant was calculated and plotted in the same way as in 5.1, results are shown in Figure 3. In this study differences are also inconsistent but with far greater magnitude than the juicers. Furthermore where the changes in shape for the juicers did show a somewhat consistent pattern, in that step size gradually decreased with each consecutive model, no such pattern exists for the toasters.

It is also noted that the overall scale of difference is greater than in the juicers. While the toasters are approximately double the size of the juicers (maximum dimension 350mm versus 170mm respectively), the magnitude of changes are greater than double those seen in the juicer study (1.21mm average change versus 0.41mm for toasters and juicers respectively).

Referring to Figure 3 (b) model 2 shows an interesting result regarding the relative differences in shape versus the relative differences in aesthetic pleasure. It is seen that there is a sharp rise in preference between variant 1 and 2 despite the relatively small difference in shape. In contrast the much larger difference in shape between variants 2 and 3 shows a far smaller increase in aesthetic pleasure. As in the case of juicer variants 4 and 5, this suggests that there is some small yet critical element of difference between toaster 1 and toaster 2 that has substantial impact on ratings of aesthetic pleasure.

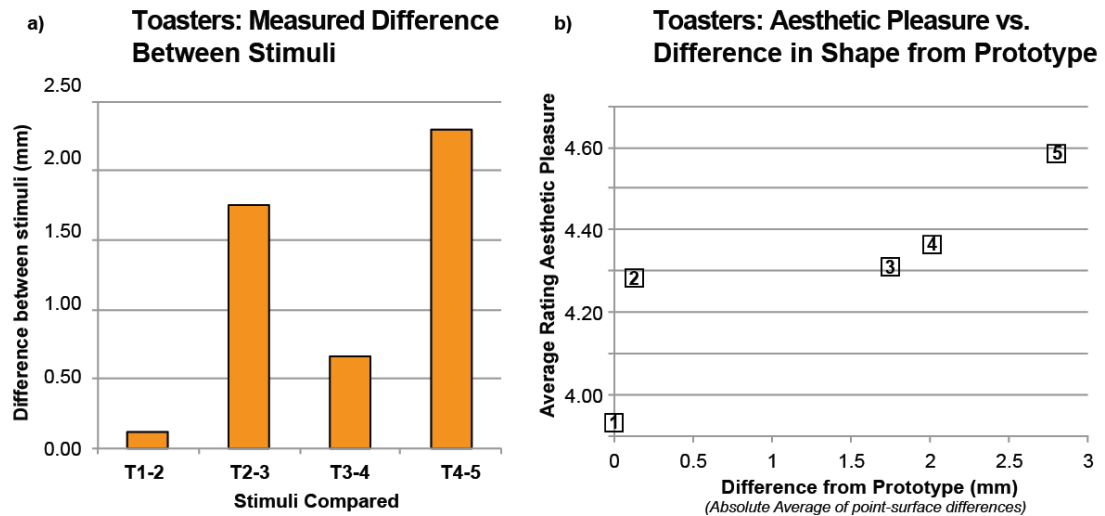


Fig. 3. Magnitude of difference between variant toaster stimuli (a) and scatter plot showing average rating for aesthetic pleasure versus difference from prototype (b).

5. Discussion

Results show that measuring the relative difference in shape of stimuli contributes to stimuli creation and research in aesthetics in a number of ways. The ability to quantify difference in shape facilitates observation of significant increases and decreases in aesthetic pleasure over relatively small changes in shape (Juicers 4 -5 and Toasters 1-2). Having an understanding of the relative magnitude of change in shape thus contributes by identifying aspects of appearance where minor changes result in significant changes in aesthetic appreciation. Hence, we are better able to identify the 'sweet spot' using objective shape difference measures. Moreover, the meta-analysis suggests an additional and unexpected contribution. Not only does there seem to exist a 'sweet spot', at some point before or after that sweet spot has been reached, aesthetic pleasure drastically declines suggesting a 'sour spot'. This 'sour spot' has to our knowledge not previously been identified. Furthermore, the data for toasters suggests that the minor change between toaster model 1 and toaster model 2 has significant effect on increasing appeal compared with the more substantial change between toaster model 2 and toaster model 3.

Considering the overall magnitude of step sizes in the case of the toasters (greater relative to the overall dimensions than the juicers, see 4.2), it seems that bigger changes from the prototype are needed to evidence achieve an optimal level of aesthetic pleasure. This echoes the reflections in [2], however the addition of these measures make it possible to evidence that the degree of deviation from the prototype that reaches the sweet spot is greater in the case of the toasters than for juicers. This then supports an explanation that relates to context rather than just the stimulus. Research shows that the relative perceived typicality of product designs within a product category is dependent on what designs people have been exposed to in daily life [10] and therefore comparisons across product categories are difficult. Hence a further application for these types of measures may be in objectively defining the total range of deviation in product shape seen across entire product categories people have potentially been exposed to.

The second contribution is in the ability to assess the relative magnitude of changes in shape between stimuli (Figures 2a and 3a). In terms of stimuli creation this provides a means for designers and researchers to validate that changes are of the magnitude intended. In other words it becomes possible to check that, for example, model 3 is more different to the prototype than model 2, as well as checking that the size of difference is consistent throughout each variation.

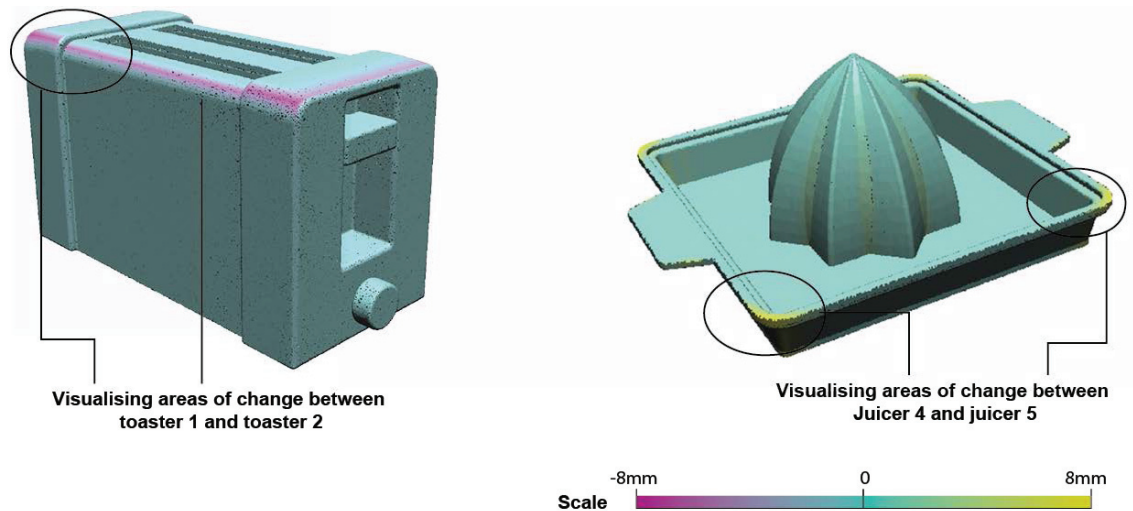


Fig. 4.(a) Designs of toasters deviating from an angular prototype in four steps; (b) Designs of juicers deviating from the rounded prototype in four steps.

The further functionality of the shape comparison tool used to visualize changes also makes a contribution here. As shown in Figure 4, it is possible to map the measures of difference onto digital models to allow visualization of the location of changes. Returning to the intentions of the designer, to observe the effects of changing angularity and considering the magnitude of changes, see that in these instances the relatively ‘potent’ effect of these changes in angularity.

Relating to the objective of finding the ‘sweet-spot’, resulting plots from assessing the juicer stimuli show the contribution in defining a measure of difference that corresponds to the optimum. It must however be noted that the selection of the trendline is significant in defining where the sweet spot lies. As seen in the case study of the juicers, the decision of viewing stimuli 5 as an anomaly affects the trend line and the position of the sweet spot. In addition, in this case study previous research defined a curvilinear relationship between the different stimuli and aesthetic pleasure. Hence the type of trend line could be defined with confidence. It follows that for future use of this technique, it is important to understand the nature of the trend/principle being investigated in order to fit a reliable trend line.

In revisiting these case studies the absolute average value for difference was used as the measure for difference. It is noted that there are methods that could also be used to quantify difference such as correlation, Euclidean or some such other distance measure. In these case studies a check of the data showed that these values demonstrated the same patterns in terms of the relative magnitude difference between steps. It is however noted that for other stimuli using different measures could also affect the measures for difference in shape and thus also impact the value/definition of a sweet spot.

The definition of the measure of difference in shape also creates the greater question of what type of measure to use and the significance of the subsequent ‘sweet-spot’. In the case of the juicer study, it is possible to read off a precise value for the sweet spot as being 1.74mm average deviation from the prototype. Despite the objectivity of this value, it is still challenging to imagine or create a design that embodies this precise degree of difference. Furthermore, given that this is an average, it is possible to embody this average magnitude of change in an almost infinite number of different shapes. As a result, it is critical to the usefulness of these techniques that the shape measures are utilized in conjunction with a design rationale. For example the knowledge that it is the angularity of designs that is being varied allows for the designer and researcher to understand that for this case, the average deviation that is optimal, is with respect to the angularity applied to certain aspects of the design. Additionally the capability to visualize magnitudes of difference over specific areas of the model (as shown in Figure 4) provides further relatability of the individual measures of shape to changes in design. Despite these factors, the relatability of

measures for difference to designed forms remains an area for further research to improve the value of this technique to design/aesthetic research.

With respect to the creation of stimuli for research into aesthetics, it is possible to see how the tool in the first instance contributes as a means to verify the size of changes. It is not evident in the two case studies, but it is possible that a designer might intend a change to be greater than the previous but in fact the change is more minor. As such the tool has potential in the role of a pre-test where the selection and/or creation of stimuli can be checked that they match the intention of the study prior to experimentation. As shown through the results, the shape comparison tool clearly contributes further insights into the design, post experimentation.

6. Conclusion

In this study we set out to explore the way in which incorporating shape comparison tools into the creation of stimuli increases the overall reliability of results. To do so we conducted a meta-analysis on the stimuli used in a previously published study into the effects of typicality on aesthetic pleasure. Results demonstrate the way in which measures for relative difference in shape show instances of substantial change in ratings for aesthetic pleasure for relatively small changes in shape and vice versa. Results also demonstrate the way in which these values facilitate the identification of the optimal level for a given aesthetic principle. Thus it is concluded that measures for difference in shape can contribute to better reliability between design principles and properties of shape. However in this study, pin-pointing precise values is highly dependent on the definition of trendlines and the type of measure selected. Hence we anticipate the need for further study into the definition of values for difference in order for these techniques to define more meaningful 'sweet-spot' with confidence.

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